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Contribution from the Bureau of Entomology, L. O. Howard, Chief.

THE SAN JOSE SCALE AND ITS CONTROL.

By A. L. QUAINTANCE,

In Charge of Deciduous Fruit Insect Investigations.

CHARACTER OF INJURY.

The San Jose or Chinese scale [1] infests practically all portions of its host plants that are above ground—the trunk, limbs, and branches—and when abundant it may occur on the leaves and fruit. Injury results from the extraction, by the scale insects, of the juices of the plant. At first this merely checks growth, but as the insects increase in number the speedy killing of the branches and twigs follows, resulting finally in the death of the plants. In addition to the extraction, by the scales, of sap as food, the puncturing of the bark by the slender sucking mouth parts results in a diseased and often pitted condition; the inner bark, or cambium, shows a reddish discoloration, as exposed in cutting with a knife, and the bark itself may crack, in stone fruits exuding drops or masses of gum. A reddening effect is also much in evidence as red rings around the scales on the bark, especially of the apple and pear, and on the fruits of these plants, though not characteristic of any one scale species.

On peach the scales have a tendency to infest to a greater extent the older limbs and branches than the newer growth, such as the wood 1 year old. On apple and pear the terminal twigs are quite generally infested, and many of the young may find their way to the fruit, settling principally in the calyx and stem cavities. Most varieties of fruit trees and plants infested from the nursery perhaps never reach fruiting condition unless treatment be given them. Peach trees will usually be killed in two or three seasons, while pear or apple trees will maintain a feeble existence much longer.

[1] *Aspidiotus perniciosus* Comstock; order Hemiptera, suborder Homoptera, family Coccidæ.

This insect, on account of its great similarity to certain other species of scale insects, may not be positively determined except by specialists. The occurrence of diseased and dying branches showing severe scale infestation furnishes strong presumptive evidence of the presence of this pest, but specimens of infested twigs should be promptly submitted to a qualified person for examination.

The appearance of a three-year-old peach tree, presumably infested from the nursery, is shown in figure 1. The principal limbs have already been killed, although new shoots have developed. A tree in this condition generally may be saved by thoroughly pruning out

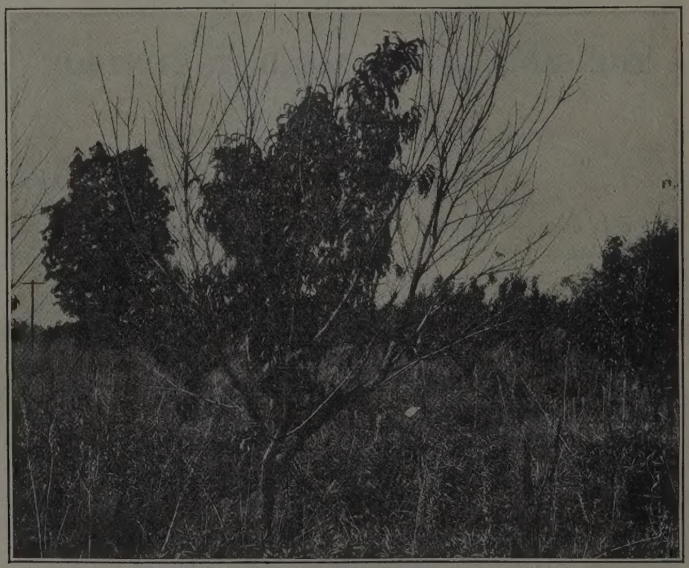

FIG. 1.—Appearance of 3-year-old peach tree badly injured by the San Jose scale, the larger branches having been killed. (Author's illustration.)

the dead and badly injured wood and subsequently effecting the control of the scale by spraying. The condition of this tree a year later is shown in figure 2, indicating the recovery following pruning and spraying. Figure 3 illustrates a badly infested six to seven year old peach orchard, the original infestation of which came from an adjacent orchard. Even in the case of peach trees so badly infested as these it is very probable that dehorning and thorough spraying would bring the trees into condition again. It is a matter of judgment, however, whether trees so seriously injured should not be removed.

The character of injury to an apple orchard, in which the trees were infested from outside sources four or five years earlier, is shown

in figure 4. Although many of the limbs and branches are injured or killed, such trees may be saved and brought into vigorous condition by thorough pruning and by insuring the control of the insect in the future.

THE INSECT DESCRIBED.

The mature San Jose scale is small, grayish in color, circular in outline, somewhat convex, and with a nipple-like prominence in the center. The female scale is about 1 millimeter in diameter (about the

FIG. 2.—Appearance of peach tree shown in figure 1, one year later. The dead and injured wood was thoroughly pruned out and the San Jose scale controlled by spraying. (Original.)

size of a pinhead); the male scale is much smaller and elongate. (See figs. 5 and 6.) The insect proper is beneath the so-called scale, this being simply a waxy covering secreted by the soft, helpless, yellow "louse" for its own protection. Where trees and plants are but slightly infested its presence is not readily detected by the casual observer, but in the case of severe infestation (see fig. 6) the bark of the tree

and limbs will present an ash-gray appearance, and on closer examination will be found thoroughly incrusted with the scales, which, when scraped with a knife, will produce a yellowish, oily fluid.

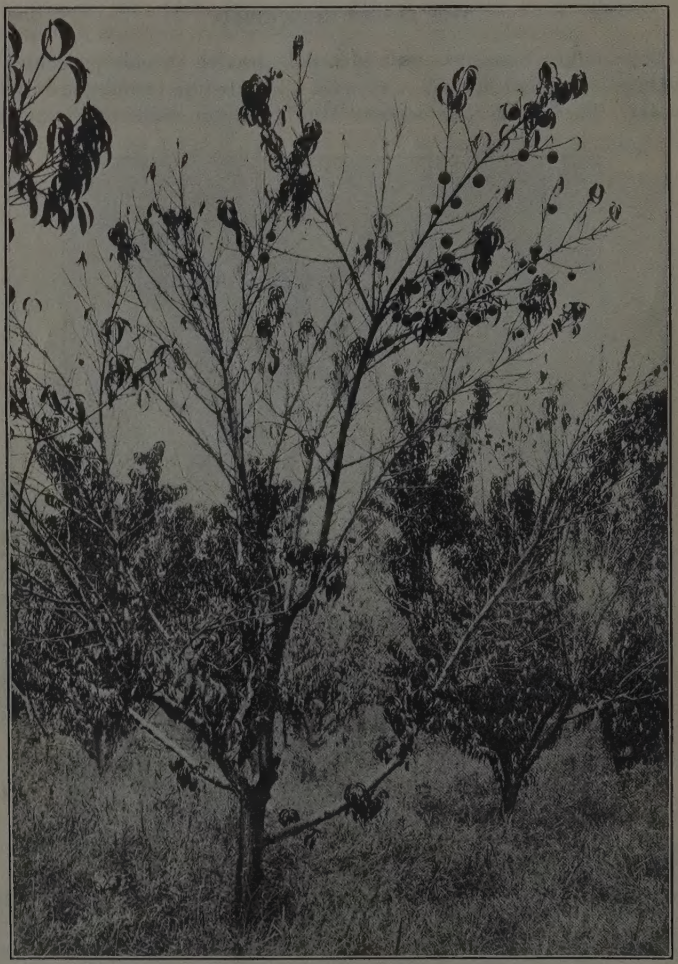

FIG. 3.—Appearance during summer of peach tree 6 to 7 years old badly injured by the San Jose scale. (Original.)

When the scales are abundant on the tree the foliage also will be thoroughly infested, giving it a spotted and diseased appearance readily observable some feet away.

NATURAL HISTORY AND HABITS.

The San Jose scale passes the winter in an immature condition fixed to the bark of the host plant, the small dark-gray or blackish scales being just discernible with the unaided eye. In early spring, with the ascent of the tree's sap, the growth of the scale begins, and early in April, in the latitude of Washington, D. C., the small, two-winged, active males issue from the male scales. After mating with the females the males die. The females continue to grow and in about a month begin the production of living young—minute,

FIG. 4.—Appearance of apple orchard badly infested by the San Jose scale; many of the limbs and branches have been killed. (Author's illustration.)

yellow, oval creatures—which by very close observation may be distinguished without the aid of a hand lens, crawling here and there on the infested plants in an effort to find a suitable place for settlement. The young insect is active for some hours, but soon settles, pushes its slender, threadlike beak into the plant, and begins to feed by sucking out the sap. After this there is no further movement from place to place, and the waxy covering, which often begins to develop before the insect has settled, soon covers it completely.

In about 12 days the insects molt, and from this time on the male and female scales may be readily distinguished. From 8 to 10 days later the males change to pupæ, and in from 24 to 26 days from birth

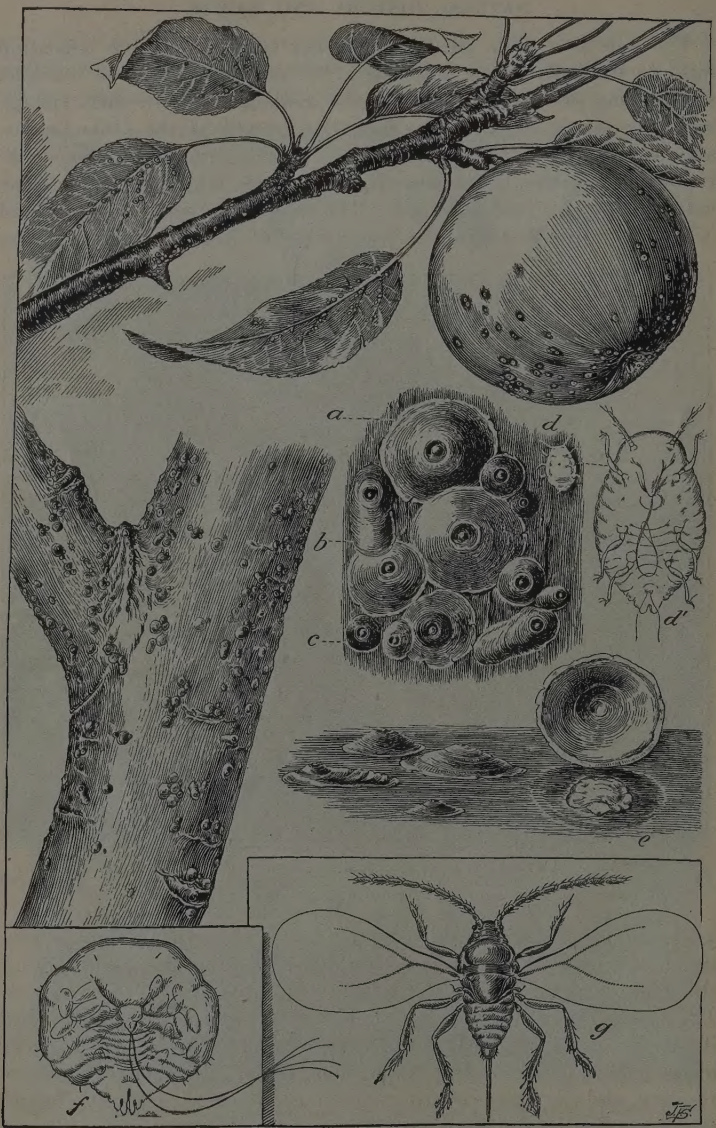

FIG. 5.—San Jose scale: *a*, Adult female scale; *b*, male scale; *c*, young scales; *d*, larva just hatched; *d'*, same, much enlarged; *e*, scale removed, showing body of female beneath; *f*, body of female insect, more enlarged; *g*, adult male of the San Jose scale. (Original.)

the adult males emerge and fecundate the females, which in turn reach maturity and begin the production of young in from 33 to 40 days from birth. An individual female may give birth, on the seasonal average, to about 400 young, and as the life cycle of the female covers but a few weeks there may be several generations a year, the number varying according to latitude. The progeny from one parent during the season have been estimated at 1,608,040,200 females. It is thus easy to understand how the insect can so quickly destroy the plants infested and why prompt remedial measures are so necessary. With the approach of the cool weather of fall, breeding

FIG. 6.—Enlarged view of a group of San Jose scales. (Original.)

gradually ceases and the scales in all stages enter hibernation. Most of the older and also most of the younger individuals perish during the winter, the survivors being those about one-third or one-half grown, as stated.

MEANS OF DISTRIBUTION.

The San Jose scale is distributed from one region to another principally on nursery stock, scions, or budding and grafting material. The danger of its dissemination in this way is fully realized, and laws are in force in the majority of States requiring the inspection of nurseries and the destruction of infested stock. Traffic in nursery produce is permissible only under the certificate of an official ento-

mologist or inspector that the stock is free from the scale. In addition to the actual inspection of nurseries, further safeguard is furnished by the practice of most nurserymen (compulsory in some States) of fumigating the plants, before distribution, with hydrocyanic-acid gas.

After the insect once becomes established in a locality its spread is accomplished by various agencies. As explained under the natural history of the insect, it is capable of movement only during a short period after birth. During this crawling stage the insects are able to pass from tree to tree where the limbs are in contact, but it is

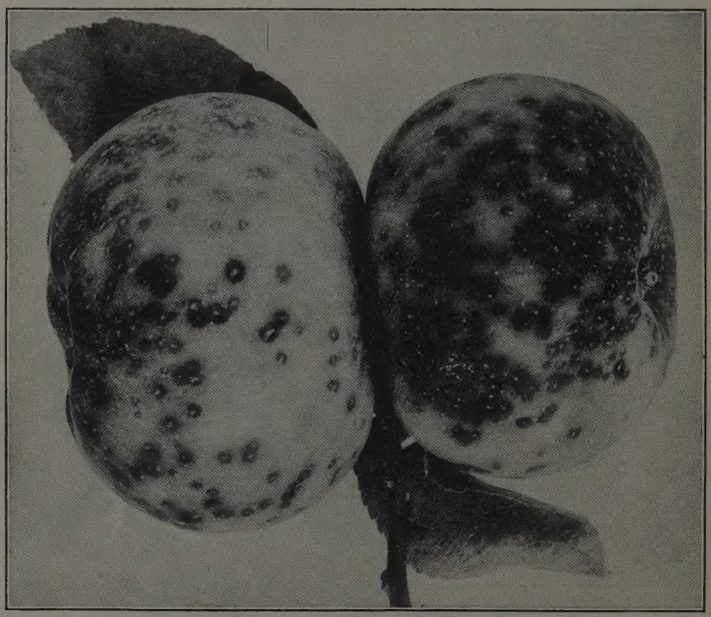

FIG. 7.—Appearance of apples infested with the San Jose scale. (Original.)

by agencies independent of itself that it is principally distributed. Prominent among these factors are birds, which may alight upon infested trees, where the young insects may crawl upon their feet and be subsequently deposited in other trees, sometimes at distances quite remote. It is probable that the young are blown by strong winds from tree to tree; and they are carried by insects, such as grasshoppers, ladybird beetles, ants, etc. The crawling "lice" may be transported considerable distances on the clothing of man, on vehicles, or on horses or other live stock which may be in orchards for any purpose.

The suggestion that the insect may be disseminated by means of scale-infested fruit (see fig. 7) has been frequently made, but it is the consensus of opinion among American entomologists that this danger is negligible.

FOOD PLANTS.

The San Jose scale infests practically all deciduous fruit trees, such as apple, pear, peach, plum, etc., and also many ornamental and shade trees. It is, however, seriously destructive to a much smaller number than that upon which it may actually maintain its existence. The following list of food plants, as compiled by Dr. W. E. Britton,[1] includes those that are commonly or badly infested:

Acacia sp. Lintner, Felt, N. Y.; Alwood, Va.
Akebia sp. Felt, N. Y.
Akebia quinata Decaisne. Alwood, Va.
Shad-bush (*Amelanchier canadensis* Medic.), Juneberry, and other species. Britton, Koehler, Conn.; Alwood, Va.
Citrus trifoliata Linn. Scott, Ga.; Alwood, Va.; Gossard, Fla.
Cornus alba Linn. var. *sibirica* Lodd. Britton, Conn.
Cornus baileyi Coult. & Evans. Gould (in N. Y.).
Cornus sanguinea Linn. Britton, Conn.
Cotoneaster sp.? Britton, Conn.; Lintner, Felt, N. Y.; Card, R. I.
Cotoneaster vulgaris Lindl. Alwood, Va.
Hawthorn (*Cratægus* sp.). Britton, Conn.; Lintner, Felt, N. Y.; Alwood, Va.; Smith, N. J.
Cratægus cordata Soland. Koehler, Conn.
English hawthorn (*Cratægus oxyacantha* Linn.). Britton, Koehler, Conn.
Cratægus coccinea Linn. Koehler, Conn.
Cratægus crus-galli Linn. Koehler, Conn.
Common quince (*Cydonia vulgaris* Pers.). Britton, Conn.; Lintner, N. Y.; Alwood, Va.
Japanese or flowering quince (*Cydonia japonica* Pers.). Britton, Koehler, Conn.; Lintner, N. Y.; Alwood, Va.; Johnson, Md.
European purple-leaved beech (*Fagus sylvatica* Linn. var. *purpurea* Ait.). Smith, N. J.
Japanese walnut (*Juglans sieboldiana* Maxim). Britton, Conn.; Alwood, Va.; Sherman, N. C.; Smith, N. J.
Common privet (*Ligustrum vulgare* Linn.). Alwood, Va.
Poplar (*Populus* sp.). Britton, Conn.; Smith, N. J.; Sanderson, Del.; Felt, N. Y.
Carolina poplar (*Populus deltoides* Marsh). Britton, Conn.; Rolfs & Quaintance, Fla.; Alwood, Va.
Lombardy poplar (*Populus nigra* Linn. var. *italica* Du Roi). Britton, Koehler, Conn.; Rolfs & Quaintance, Fla.; Alwood, Va.
Almond (*Prunus amygdalus* Stokes). Lintner, N. Y.; Alwood, Va.
Apricot (*Prunus armeniaca* Linn.). Lintner, Felt, N. Y.; Alwood, Va.; Smith, N. J.
Sweet cherry (*Prunus avium* Linn.). Britton, Conn.; Lintner, Felt, N. Y.; Alwood, Va.; Smith, N. J.; Cockerell, N. Mex.
Prunus pumila Linn. Koehler, Conn.
Sand cherry (*Prunus pumila* var. *besseyi* Waugh). Alwood, Va.
Purple-leaved plum (*Prunus cerasifera* Ehrh. var. *atropurpurea* Dipp. (*P. pissardi*). Britton, Conn.; Felt, N. Y.

[1] Britton, W. E. List of hardy trees, shrubs, and vines commonly or badly infested [by the San Jose scale]. Conn. Agr. Expt. Sta., Rpt. for 1902, pt. II., 2d Rpt. State Entomologist, p. 132–138. 1903.

European plum (*Prunus domestica* Linn.). Britton, Conn.; Alwood, Va.
Wild goose plum (*Prunus hortulana* Bailey). Alwood, Va.
Flowering almond (*Prunus japonica* Thunb.). Britton, Conn.; Felt, N. Y.
Beach plum (*Prunus maritima* Waugh). Koehler, Britton, Conn.
Peach (*Prunus persica* Sieb. & Zucc.). Britton, Koehler, Conn.; Lintner, Felt, N. Y.; Alwood, Va.; Cockerell, N. Mex.
Japanese plum (*Prunus triflora* Roxbg.). Britton, Koehler, Conn.; Alwood, Va.
Prunus serotina Ehrh. Koehler, Conn.
Chokecherry (*Prunus virginiana* Linn.). Koehler, Conn.
Hop tree (*Ptelea trifoliata* Linn.). Fernald, Mass.
Pear (*Pyrus communis* Linn.). Britton, Koehler, Conn.; Lintner, Felt, N. Y.; Alwood, Va.; Cockerell, N. Mex.
Sand pear, including Kieffer (*Pyrus sinensis* Lindl.). Alwood, Va.
Pyrus baccata Linn. Koehler, Conn.
Apple (*Pyrus malus* Linn.). Britton, Koehler, Conn.; Lintner, Felt, N. Y.; Alwood, Va.; Doten, Nev.; Cockerell, N. Mex.
Crab apple (*Pyrus* sp.). Britton, Conn.
Gooseberry (*Ribes oxyacanthoides* Linn.). Britton, Conn.; Lintner, Felt, N. Y.; Alwood, Va.; Troop, Ind.
Missouri or flowering currant (*Ribes aureum* Pursh.). Lintner, N.Y.
Currant (*Ribes rubrum* Linn.). Britton, Conn.; Lintner, Felt, N. Y.
Black currant (*Ribes nigrum* Linn.). Alwood, Va.
Rosa sp. Britton, Conn.; Lintner, N. Y.; Alwood, Va.; Cockerell, N. Mex.; Burgess, Ohio; Troop, Ind.; Gould, Md.; Scott, Ga.
Rosa carolina Linn. Koehler, Conn.
Rosa lucida Ehrh. Koehler, Conn.
Rosa virginiana Mill. Koehler, Conn.
Rosa rugosa Thunb. Britton, Koehler, Conn.
Willow (*Salix* sp.). Britton, Conn.; Felt, N. Y.; Sanderson, Del.
Salix lucida Muhl. Koehler, Conn.
Laurel-leaved willow (*Salix pentandra* Linn.). Lintner, N. Y.; Alwood, Va.
Salix vitellina Linn. Koehler, Conn.
Weeping willow (*Salix babylonica* Linn.). Lintner, N. Y.; Alwood, Va.
Salix humilis Marsh. Koehler, Conn.
Salix incana Schrank. Koehler, Conn.
Mountain ash (*Sorbus* sp.). Felt, N. Y.; Hunter, Kans.
American mountain ash (*Sorbus americana* Marsh). Britton, Koehler, Conn.; Alwood, Va.
European mountain ash (*Sorbus aucuparia* Linn.). Britton, Koehler, Conn.
Black chokeberry (*Sorbus melanocarpa* C. Koch [*Aronia nigra* Koehne]). Koehler, Conn.
Snowberry (*Symphoricarpos racemosus* Michx.). Felt, N. Y.; Smith, N. J.
Common lilac (*Syringa vulgaris* Linn.). Burgess, Ohio; commissioner of agriculture, N. Y.; Troop, Ind.; Alwood, Va.
Persian lilac (*Syringa persica* Linn.). Britton, Conn.
Basswood, linden (*Tilia* sp.). Britton, Conn.; Lintner, commissioner of agriculture, N. Y.
American linden or basswood (*Tilia americana* Linn.). Britton, Conn.; Alwood, Va.
Osage orange (*Toxylon pomiferum* Raf.). Britton, Conn.; Lintner, Felt, N. Y.; Alwood, Va.
Elm (*Ulmus* sp.). Lintner, N. Y.; Webster, Ohio; Troop, Ind.
American elm (*Ulmus americana* Linn.). Britton, Koehler, Conn.; Alwood, Va.
English or European elm (*Ulmus campestris* Smith). Britton, Conn.; Felt, N. Y.; Smith, N. J.

This list might be materially extended by recording those plants upon which the insect has at various times been taken but to which it is not especially injurious. The fears earlier expressed that the scale would eventually seriously infest our native forest growth have not been borne out, and in effect it requires treatment only on fruit trees, bush fruits, and ornamental trees and plants.

NATURAL ENEMIES.

The San Jose scale is subject to attack by numerous predaceous and parasitic enemies, which render important service in its control. Practically, however, the combined influence of these several agencies is not sufficient to make up for the enormous reproductive capacity of this insect. To preserve the plants from destruction, its control must be accomplished by artificial means, such as the use of sprays.

FIG. 8.—The pitiful ladybird: *a*, Beetle; *b*, larva; *c*, pupa; *d*, blossom end of pear, showing scales with larvæ of ladybird feeding on them, and pupæ of ladybird attached within the calyx. All greatly enlarged. (From Howard and Marlatt.)

Among the more common predaceous insects which are observed feeding on the scale is the so-called pitiful ladybird,[1] illustrated in figure 8. This very small, convex, black beetle may generally be found by any observant person on scale-infested trees.

Another species that feeds very commonly on this and other scale insects is the twice-stabbed ladybird.[2] This is a very near relative

[1] (*Pentilia*) *Microweisea misella* Lec.

[2] *Chilocorus bivulnerus* Muls.

and almost identical in appearance with the Asiatic ladybird[1] (fig. 9), which was introduced into this country from China through the activities of Mr. C. L. Marlatt, of the Bureau of Entomology, in the hope that its introduction would result in the control of this insect. The Asiatic ladybird, however, unfortunately proved to be subject to certain native parasites, while the necessity of spraying for the scale destroyed its food supply to such an extent that it was unable to maintain its existence.

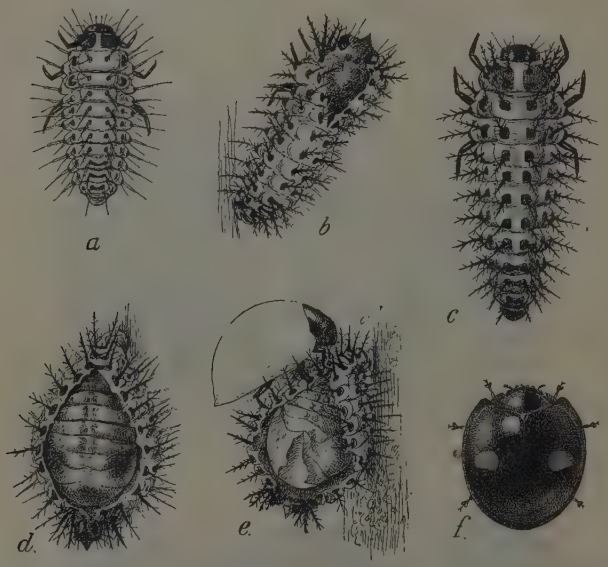

FIG. 9.—The Asiatic ladybird, almost identical with the twice-stabbed ladybird, predatory on the San Jose scale: *a*, Second-stage larva; *b*, cast skin of same; *c*, full-grown larva; *d*, method of pupation, the pupa being retained in the split larval skin; *e*, newly emerged adult not yet colored; *f*, fully colored and perfect adult. All enlarged to the same scale. (From Marlatt.)

In addition to the enemies just mentioned, there are certain very minute, four-winged flies (see fig. 10) belonging to the parasitic Hymenoptera, which are true parasites of scale insects. These place their eggs beneath the scales, some species attacking the scale insect while others attack the eggs. The resulting grubs kill the insect or devour the eggs. When the parasite has become fully developed it escapes through a small, round hole which it gnaws through the scale. Parasitism of the San Jose scale by these insects can be determined by inclosing in a glass vial a badly infested twig, for in the course of a few days the minute flies, if present, will begin to emerge. Dr. L. O. Howard and Mr. R. A. Cushman have prepared the

[1] *Chilocorus similis* Rossi.

following list of parasites which have been reared from the San Jose scale: *Aphelinus fuscipennis* How., *Aphelinus mytilaspidis* LeB., *Aphelinus diaspidis* How., *Aspidiotiphagus citrinus* How. (fig. 10), *Anaphes gracilis* How., *Physcus varicornis* How., *Prospaltella aurantii* How., *Prospaltella perniciosi* Tower, *Prospaltella fasciativentris* Gir., *Ablerus clisiocampae* Ashm., *Rhopoideus citrinus* How., *Perissopterus pulchellus* How., *Arrhenophagus chionaspidis* Auriv., *Anagrus spiritus* Gir., *Signiphora nigrita* Ashm., *Coccophagus immaculatus* How., *Coccophagus lecanii* Fitch, and *Microterys* sp.

While the benefits arising from the work of these parasites are undoubtedly great, the percentage of control of the scale thus accomplished varies greatly with the locality and the time of year, and from season to season. The highest percentage of parasitism thus far observed, and far in excess of the average, is 90. The remaining

FIG. 10.—*Aspidiotiphagus citrinus*, a hymenopterous parasite of the San Jose scale. Greatly enlarged. (From Howard.)

10 per cent of healthy scales would suffice for reproduction of the scale in injurious numbers. It is, therefore, readily seen that, even with this high percentage of parasitism, the control of the scale by these agencies can not be depended upon.

Considerable attention has been given to the subject of fungous diseases of the San Jose scale, and numerous attempts conducted in a thoroughly scientific manner, notably by Prof. P. H. Rolfs, director of the Florida Agricultural Experiment Station, have been made to utilize one of these parasitic plants in the control of the insect. The fungus in question, *Sphaerostilbe coccophila*, is cosmopolitan in its distribution, infesting many armored scale insects,[1] and in Florida and the territory adjacent to the Gulf it is quite generally present on scales in orchards and on shade and forest trees. Its abundance and effectiveness, however, depend upon certain weather conditions, and therefore vary considerably.

[1] Subfamily Diaspinæ.

CONTROL MEASURES.

As has been already stated, the San Jose scale, in the absence of proper treatment, will quickly bring about the death of many plants of economic importance. Its discovery, therefore, whether in orchards or on prized fruit trees and other plants in the yard, should call for prompt steps toward its control. It has been amply demonstrated that the scale may be very successfully controlled, and practically its presence merely requires one thorough treatment during the dormant period each year. On account of the general distribution of the pest extermination measures are, in most cases, out of the question.

Complaint sometimes comes from orchardists who have the scale to contend with that the control of the insect is neglected by their neighbors, and they believe this neglect adds materially to their own work. Undoubtedly the scale will spread from orchard to orchard, but thorough annual sprayings will prevent important injury irrespective of neglect in adjacent orchards.

Where plants are thoroughly incrusted, with consequent death of branches and stunting of growth, it will generally be advisable to dig out the trees at once and replace with new ones. Before spraying infested trees the dead and weakened wood should be pruned out, which will simplify the work of spraying and will hasten the formation of new, sound wood.

THE WASHES IN USE AGAINST THE SAN JOSE SCALE.

There are several scale washes which may be employed in the control of the insect, and the one should be selected which can be most conveniently used and which is economical under the circumstances. Thus, for spraying on a large scale, the orchardists could properly afford expenditures for the construction of cooking outfits for lime-sulphur wash which would not be justified where only a few trees were involved. For a few plants it would be better to use some one of the prepared washes put up by manufacturers. In fact, many large orchardists prefer to use sprays of this class in preference to making the washes at home. The possibility of injury to the trees from the sprays must also be borne in mind. All treatments, if possible, should be made during the dormant period (that is to say, in late fall or early spring, or even during the winter in mild climates), since at this time washes may be applied at much greater strengths than when the trees are in foliage. The aim is to use the wash about as strong as the tree will stand, thereby securing the maximum killing effect upon the insects. Used in this way the washes of the petroleum or kerosene series are most likely to cause injury to the fruit buds and tender twigs, and the lime-sulphur washes least likely to do so. Fish-oil soap sprays as recommended for dormant trees are comparatively safe, though reports are at hand of injury to

fruit buds, especially from fall applications. Stone fruits, such as peach, plum, etc., are more susceptible to injury from sprays than apple and pear, and on the former the lime-sulphur sprays should always be used. Petroleum and miscible oils are more frequently used on apple and pear, and owing to their spreading and penetrating qualities are perhaps more effective in destroying the scales on the terminal twigs, which are infested to a greater extent in the case of these fruits. The several sprays in use may be considered under the following headings: (1) Lime-sulphur wash series; (2) petroleum-oil series (including miscible oils), and (3) soap washes.

LIME-SULPHUR WASH SERIES.

For several years the cooked lime-sulphur wash was the main reliance in the control of the scale. It is made according to the following formula:

Stone lime	pounds	20
Sulphur (flour or flowers)	do	15
Water to make	gallons	50

Heat in a cooking barrel or vessel about one-third of the total quantity of water required. When the water is hot add all the lime and at once add all the sulphur, which previously should have been made into a thick paste with water. After the lime has slaked, about another third of the water should be added, preferably hot, and the cooking should be continued for one hour, when the final dilution may be made, using either hot or cold water, as is most convenient. The boiling due to the slaking of the lime thoroughly mixes the ingredients at the start, but subsequent stirring is necessary if the wash is cooked by direct heat in kettles. If cooked by steam, no stirring will be necessary. After the wash has been prepared it must be well strained as it is being run into the spray tank. It may be cooked in large kettles, or preferably by steam in barrels or tanks. This wash should be applied promptly after preparation, since, as made by this formula, there is crystallization of the sulphur and hardening of the sediment upon cooling. Probably comparatively few fruit growers at the present time prepare the wash according to this old method, but employ the commercial or homemade concentrate.

Commercial Lime-Sulphur Concentrates.

The inconvenience experienced in preparing the lime-sulphur wash according to the foregoing formula by cooking with steam or in open kettles at home has been one of the principal objections to this spray. Manufacturers have, therefore, put on the market concentrated solutions of lime-sulphur which have only to be diluted with water for use. These commercial washes, if used at proper strength, have proved to be quite as satisfactory in controlling the scale as

the old-formula lime-sulphur wash, and, although somewhat more expensive, have been adopted by many of the commercial orchardists in preference to the "20–15–50" formula. They are especially useful for the smaller orchardists whose interests do not warrant the construction of a cooking plant.

Homemade Lime-Sulphur Concentrates.

The question of the preparation at home of concentrated lime-sulphur solutions which will not crystallize upon cooling, thus duplicating the commercial product, has been investigated by the Bureau of Entomology, as well as by numerous experiment station entomologists, notably by Profs. Stewart, Cordley, Parrott, and others. It has been demonstrated that it is practicable for orchardists to prepare concentrated stock solutions of lime-sulphur wash for immediate or later use, and many orchardists employ this plan. The necessary details for the preparation at home of lime-sulphur concentrates are given below.

Directions for Preparation of Lime-Sulphur Concentrates.

The so-called 50–100–50 formula, composed of 50 pounds of lime, 100 pounds of sulphur, and water to make 50 gallons, has been generally recommended for the preparation of a homemade concentrated lime-sulphur solution. Some advise the use of five or six pounds of sulphur more than above stated in order to have a slight excess of this ingredient over the lime. The method of preparation is to boil together in the necessary water the respective ingredients for from 50 minutes to an hour. A good grade of fresh stone lime containing not less than 90 per cent of calcium oxid is necessary for the best results. Hydrated lime is sometimes used, but it is necessary to use a good grade and at least 20 per cent more of this form of lime is required, as it contains a high percentage of moisture.

Place enough water in the cooking vessel to finish with 50 gallons of the solution; bring the water to the boiling point, then put in the lime and immediately add the sulphur. If the plant is equipped with an agitator, this should be started with the addition of lime and sulphur. If there is no mechanical agitator, the mixture must be stirred vigorously by hand until the lime is slaked, and necessary agitation must be given throughout the time of cooking. If the solution is to be put in barrels without filtering, it should be drawn off as soon as the period of cooking is completed, and allowed to run through a 30-mesh strainer into the barrels. The agitation should be continued while the solution is being drawn off so that there will be an equal distribution of the sludge in the different storage receptacles.

The density of the concentrate, made according to the formula 50–100–50, has varied, in the experience of the Bureau of Entomology, from 24 to 28 degrees Baumé, and theoretically should be 26° by this scale. It is quite desirable for economy in storage space to prepare as highly concentrated a solution as possible. This can be done with reduced quantity of water after the following formula, which will give a solution of a density of from 32 to 34 degrees Baumé.

Fresh stone lime	pounds..	80
Commercial ground sulphur	do....	160
Water to make, of the finished product	gallons..	50

While this formula gives about 50 per cent in volume of sludge, after allowing the solution to settle for 24 hours, there is only about 5 to 10 per cent in volume of insoluble material, which would be removed in the straining process. This volume of sludge will not be objectionable in spraying, provided the insoluble material has been properly strained out.

HANDLING AND STORAGE.

It is very desirable in most cases to make up a supply of lime-sulphur solution during the winter or early spring, before spraying operations begin. It is quite feasible to do this, as the solution can be kept a year or more when properly stored. It should be placed in barrels or other tight receptacles and carefully stoppered so as to exclude the air as much as possible, as this slowly causes the wash to deteriorate. The barrels or other container should be completely filled, so that there will be little or no air space above the surface of the liquid. In the preparation of the lime-sulphur concentrate at home the disposition of the sludge is a question of practical importance. Commercial manufacturing plants are usually supplied with a filter press by means of which the wash, as it comes from the cooking tank, is filtered, freeing it from sludge and sediment. There seems, however, to be no objection to storing the solution without removal of sludge, though the sediment should be strained out as already stated.

Lime-sulphur solution should not be allowed to freeze, as this greatly reduces its strength. It does not freeze easily, however, and the temperature at which it freezes varies with its strength; the stronger the solution, the less easily it is frozen. It will stand a considerably lower temperature without freezing than will water.

COOKING PLANTS.

Lime-sulphur concentrate may be made by orchardists with very simple appliances, such as a large kettle suspended on a pole or raised from the ground on loose stones. One or two such kettles embedded in masonry would be more convenient, however, and would permit the

development of necessary facilities for water supply. (See fig. 11.) Ordinary feed cookers or jacketed kettles are also very satisfactory. Small steam boilers of a few horsepower capacity serve especially well for a medium-sized orchard.

Where the amount of concentrate to be made is considerable, as for a large orchard or for the fruit growers of a neighborhood, it will pay to construct a more elaborate cooking plant. A convenient outfit is shown in figure 12. In the construction of these plants careful attention should be given to the arrangement of the cooking vessel, the water supply, and the arrangement for drawing off the cooked wash. A

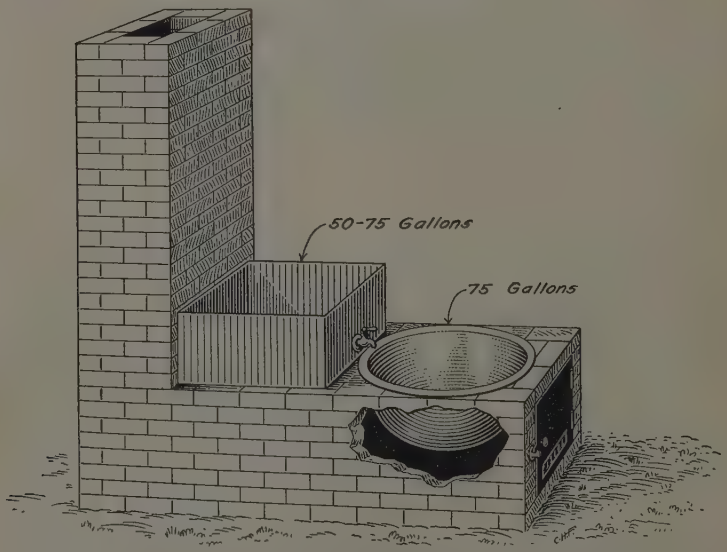

FIG. 11.—Lime-sulphur cooking outfit for preparing wash for small to medium sized orchards. Prepared by E. W. Scott. (Original.)

12-horsepower boiler will furnish sufficient steam for a cooker of 300 gallons capacity. However, if a steam engine is to be used for running the agitator, a somewhat larger boiler will be necessary. The cooking vessel may be either of wood or iron, though an iron vessel is usually more satisfactory owing to the difficulty in preventing leakage of wooden vessels. If the cooking vessel is not provided with a pump it should be so elevated that the cooked concentrate may be drawn off by gravity into a settling tank or storage vessels. Vinegar barrels, or barrels which have been used for acids, should not be employed in storing the solution, as the acid breaks down the concentrate. Kerosene oil barrels and whisky barrels are used to a large extent.

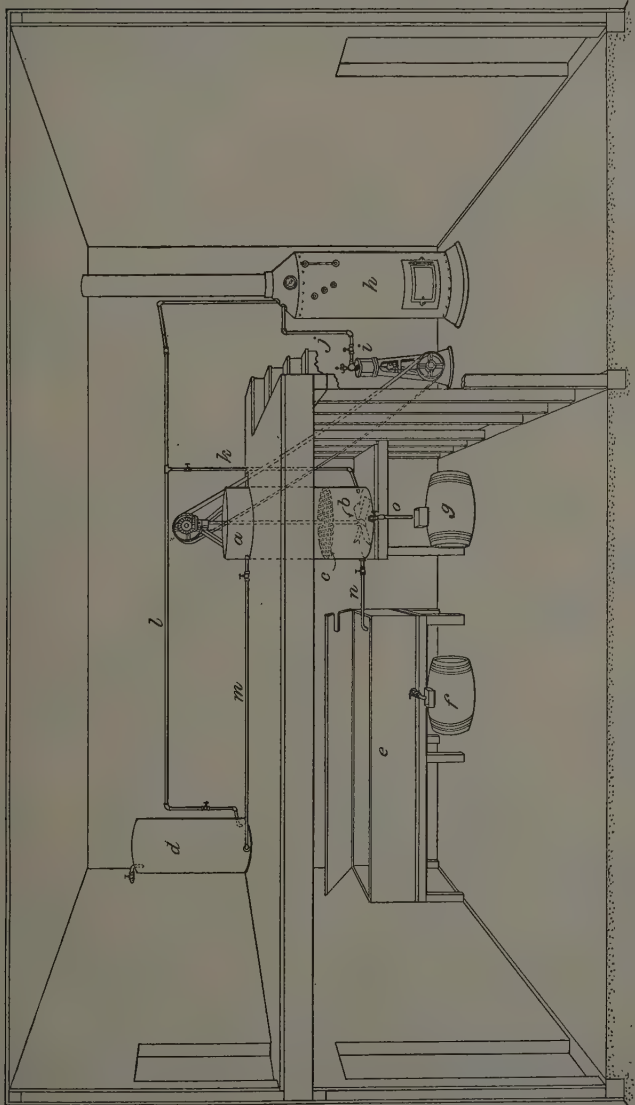

FIG. 12.—Diagrammatic representation of arrangement of parts in a large lime-sulphur cooking plant: *a*, Cooking tank; *b*, agitator; *c*, screen for support of lime and sulphur; *d*, water supply tank; *e*, settling tank; *f*, barrel for storing the lime-sulphur concentrate; *g*, same when concentrate is drawn directly from cooking vessel; *h*, steam boiler; *i*, steam engine for running agitator; *j*, steam pipe from boiler to engine; *k*, steam pipe for cooking the lime-sulphur concentrate; *l*, steam pipe for heating water in water supply tank; *m*, pipe from water supply tank to cooking vat; *n*, pipe and valve for drawing off concentrate from cooking vat to settling tank; *o*, pipe and valve for drawing off concentrate from cooking vat directly to storage barrel. Prepared by E. W. Scott. (Original.)

DILUTION.

It is very important to test with a hydrometer the strength of all lime-sulphur solutions prepared, to determine the proper amount of the concentrate that should be used for a given quantity of water. There are two kinds of these hydrometers, one with the Baumé scale and the other with the specific gravity scale, and hydrometers may be purchased which have both scales on the same instrument. The Baumé scale hydrometer is most commonly used. The clear solution at a temperature of about 60° F. should be used for the testing. If, however, the sludge has not been filtered out, the contents of the barrel or other container should be thoroughly stirred before the required amount for testing is taken out.

Below is given a table (Table I) from which can be determined the amount of dilution for concentrates for each degree Baumé from 20 to 36, and the corresponding specific-gravity reading. Figure 13 illustrates the kind of hydrometers to be used in testing lime-sulphur concentrates.

TABLE I.—*Dilution table for concentrated lime-sulphur solutions.*

Degrees Baumé.	Specific gravity.	Number gallons concentrated lime-sulphur to make 50 gallons spray solution.			Degrees Baumé.	Specific gravity.	Number gallons concentrated lime-sulphur to make 50 gallons spray solution.		
		Summer or foliage strength.	Winter or dormant strength.				Summer or foliage strength.	Winter or dormant strength.	
			San Jose scale.	Blister mite.				San Jose scale.	Blister mite.
36	1.330	1¼	5¼	4¾	27	1.229	2	8	6¾
35	1.318	1¼	5¼	5	26	1.218	2	8¼	7¼
34	1.306	1½	6	5	25	1.208	2	8¾	7½
33	1.295	1½	6¼	5¼	24	1.198	2¼	9¼	8
32	1.283	1½	6¼	5¾	23	1.188	2¼	9¾	8¼
31	1.272	1¾	6¾	5¾	22	1.179	2¼	10¼	8¾
30	1.261	1¾	7	6	21	1.169	2½	11	9¼
29	1.250	1¾	7¼	6¼	20	1.160	2½	11½	9¾
28	1.239	1¾	7½	6½					

In spraying for the San Jose scale and the pear-leaf blister mite about 5 per cent more of the solution should be used than the table of dilutions indicates, if the sludge has not been filtered out. In summer spraying, however, no allowance for sludge is necessary, as a large percentage of this is composed of finely divided sulphur, which is of value.

LIME-SULPHUR WASHES FOR SUMMER SPRAYING OF THE SAN JOSE SCALE.

The lime-sulphur washes discussed on the preceding pages are intended for use on trees in a dormant condition. It sometimes happens that owing to unfavorable weather conditions during the time of the dormant spraying, or for other reasons, the insect has not been properly destroyed, and it becomes desirable to spray the trees during the

summer. Under these circumstances much benefit will follow summer spraying for the San Jose scale, but this work should be regarded as a temporary expedient to prevent undue increase of the insect until the more effective dormant treatment may be applied.

Either the commercial or homemade lime-sulphur concentrate may be used for summer spraying (except on stone fruits), but they must be used in a much more dilute condition than during the winter. The dilute lime-sulphur spray has come into very extended use as a fungicide[1] and is used on pome fruits at the rate of 1½ gallons of the concentrate, registering from 32 to 34 degrees on the Baumé scale, to 50 gallons of water. The use of the lime-sulphur wash as a fungicide will constitute sufficient sprayings for the scale, provided attention is given in spraying to coat, in addition to the leaves and fruit necessary in fungicidal work, also the limbs, branches, and twigs.

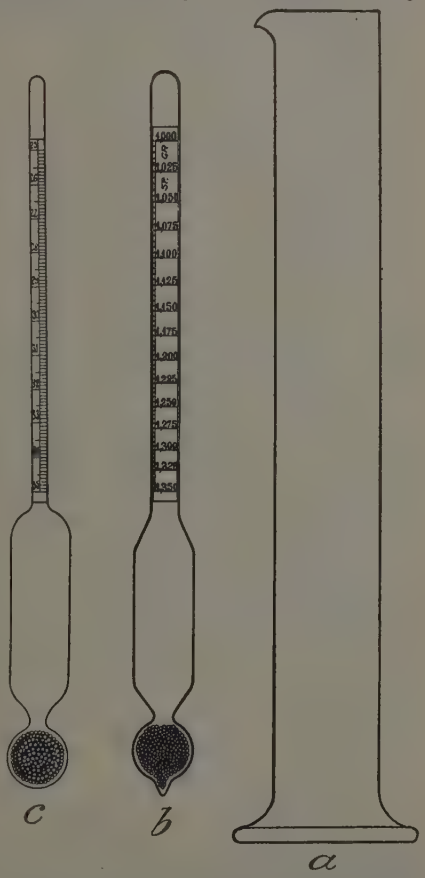

FIG. 13.—Apparatus for determining specific gravity of lime-sulphur concentrate: *a*, Cylinder for liquid to be tested; *b*, specific gravity spindle; *c*, Baumé spindle. (Original.)

Young scale insects from individuals which may have escaped the treatment have a decided tendency to migrate onto the fruit. The presence of these insects on the fruit is very objectionable, especially on apples intended for export trade, as scale-infested fruit is excluded from entry by certain foreign governments, and is discriminated against by buyers generally. The influence of sulphur sprays used as fungicides in trees and foliage in checking the settling of young scales on the fruit is shown in Table II. These data were obtained by Mr. E. W. Scott, of the Bureau of Entomology, in the course of some experimental work during 1911 at Fennville, Mich.

[1] Quaintance, A. L., and Scott, W. M. The more important insect and fungous enemies of the fruit and foliage of the apple. U. S. Dept. Agr., Farmers' Bul. 492, 48 p., 21 figs. 1912.

TABLE II.—*Results of lime-sulphur sprays in preventing marking of fruit by the San Jose scale.*

Plat No.	Treatments.[1]	Variety.	Number of apples infested.	Number of apples not infested.	Total number of apples.	Percentage of uninfested apples.
1	Commercial lime sulphur, 1½ to 50; sprayed May 12, 25, June 14, July 25.	Rhode Island Greening.	137	1,606	1,743	92.13
2	....do....	Baldwin	80	778	858	90.67
3	Home boiled lime sulphur, May 12, 25, June 14, July 25.	Greening	79	3,939	4,018	98.03
4	....do....	Baldwin	37	1,813	1,850	98.00
5	Commercial lime sulphur, 1½ to 50; May 12, 25, June 14, July 25.	....do....	13	298	311	95.81
6	Bordeaux mixture (3–4–50), May 12, 25, June 14, July 25.	Greening	843	1,055	1,898	55.58
7	....do....	Baldwin	525	500	1,025	48.78
8	Unsprayed	Greening	796	805	1,601	50.28
9	....do....	Baldwin	809	190	999	19.01

[1] All treatments had 2 pounds of arsenate of lead to each 50 gallons of spray, except in case of plat 5, which had the poison in the application of May 12 only.

Summer spraying of peach trees and other stone fruits for the scale may also be desirable because of ineffective work during the dormant period of the trees. Under such circumstances the self-boiled lime-sulphur mixture should be used, since the foliage of the peach will not stand the diluted lime-sulphur mixture previously indicated for the apple, pear, etc. This self-boiled lime-sulphur wash is made up according to quite a different formula from any of the washes heretofore mentioned, and has come into general use as a fungicide for the control of peach scab and brown-rot.[1] Orchardists spraying for these troubles on peaches and other stone fruits may at the same time accomplish much in preventing the increase of the scale by thoroughly coating the limbs and branches of the trees while making the applications to the foliage and fruit for the control of the fungous troubles mentioned. The self-boiled lime-sulphur wash may be made as follows:

Stone lime	pounds	8
Sulphur (flour or flowers)	do	8
Water to make	gallons	50

The lime should be placed in a barrel and enough water poured on almost to cover it. As soon as the lime begins to slake the sulphur should be added, after first running it through a sieve to break up the lumps. The mixture should be stirred constantly and more water added as needed to form a thick paste at first and then gradually a thin paste. The lime will supply enough heat to boil the mixture several minutes. As soon as it is well slaked water should be added to cool the mixture and prevent further cooking. It is then ready to be strained into the spray tank, diluted, and applied.

[1] Scott, W. M., and Quaintance, A. L. Spraying peaches for the control of brown-rot, scab and curculio. U. S. Dept. Agr., Farmers' Bul. 440, 40 p, 14 figs. 1911.

The stage at which cold water should be poured on to stop the cooking varies with different grades of lime. Some limes are so sluggish in slaking that it is difficult to obtain enough heat from them to cook the mixture at all, while other limes become intensely hot on slaking, and care must be taken not to allow the boiling to proceed too far. If the mixture is allowed to remain hot 15 or 20 minutes after the slaking is completed the sulphur gradually goes into solution, combining with the lime to form sulphids, which are injurious to peach foliage. It is therefore very important, especially with hot lime, to cool the mixture quickly by adding a few buckets of water as soon as the lumps of lime have slaked down. The intense heat, violent boiling, and constant stirring result in a uniform mixture of finely divided sulphur and lime, with only a very small percentage of the sulphur in solution. It should be strained to take out the coarse particles of lime, but the sulphur should be carefully worked through a strainer. The mixture can be prepared in larger quantities if desirable, say enough for 200 gallons at a time, making the formula 32 pounds of lime and 32 pounds of sulphur to be cooked with a small quantity of water (8 or 10 gallons) and then diluted to 200 gallons.

COMMERCIAL POWDERED SULPHUR COMPOUNDS.

Within the past two or three years certain manufacturers have offered for sale, in a dry powdered condition, compounds of sulphur which are to be dissolved in water for the preparation of the spray. These compounds give promise of being satisfactory as scale washes, and if so, will undoubtedly meet with prompt favor with orchardists, since by their use there is a distinct saving in freight, and they are much more convenient in handling and storing.

PETROLEUM-OIL SERIES.

Under the heading "Petroleum-oil series" are to be included kerosene and crude petroleum, either pure or in emulsion, and the so-called miscible oils.

Pure Kerosene.

Pure kerosene has been recommended to a greater or less extent for spraying trees badly infested with the scale, but it has never been very generally employed. There is no question of the efficiency of such an application in the destruction of the insects, but the great danger of injury to the plants precludes its general application. Treatments of pure kerosene should be made only to dormant trees and during bright days and should be applied through a nozzle with a very fine aperture. Only the minimum amount of kerosene necessary to cover the trees should be given, and care is necessary that the liquid does not puddle around the roots of the trees.

Pure Crude Petroleum.

Pure crude petroleum is used in identically the same manner as pure kerosene, and the same cautions as to its use should be remembered. The crude oil employed in the East is known as "insectide oil" and has a specific gravity of 43 to 45 degrees on the Baumé scale.

Kerosene Emulsion (Stock Solution 66 Per Cent Oil).

Kerosene emulsion is made after the following formula:

Kerosene (coal oil, lamp oil)	gallons..	2
Fish-oil soap or laundry soap (or 1 quart of soft soap)	pound..	½
Water	gallon..	1

Fig. 14.—Bucket spray pump suitable for use in yards. (Author's illustration.)

Dissolve the soap in boiling water; then remove the vessel from the fire. Immediately add the kerosene and thoroughly agitate the mixture until a creamy solution results. The stock emulsion may be more conveniently made by pouring the mixture into the tank of a spray pump and pumping the liquid through the nozzle back into the tank for some minutes. The stock solution, if well made, will keep for some months, and is to be diluted before using. In order to make a 10 per cent spray (the strength for trees in foliage), add to each 1 gallon of the stock solution about 5⅔ gallons of water. For 20 and 25 per cent emulsions (for use on dormant trees and plants), use, respectively, about 2⅓ gallons and 1⅔ gallons of water for each 1 gallon of stock emulsion. Agitate the mixture in all cases after adding the water. The preparation of the emulsion will be simplified by the use of a naphtha soap. No heat will then be required, as the kero-

sene will combine readily with the naphtha soap in water when thoroughly agitated. Of naphtha soap, however, double the quantity given in the foregoing formula will be required, and soft or rain water should be used in making the emulsion. In regions where the water is "hard" this should first be broken with a little caustic potash or soda, such as common lye, before use for dilution, to prevent the soap from combining with the lime or magnesia present, thus liberating some of the kerosene; or rain water may be employed.

Crude Petroleum Emulsion.

Crude petroleum emulsion may be prepared in identically the same way as described for kerosene emulsion, substituting crude petroleum for kerosene. The same dilutions for winter and summer

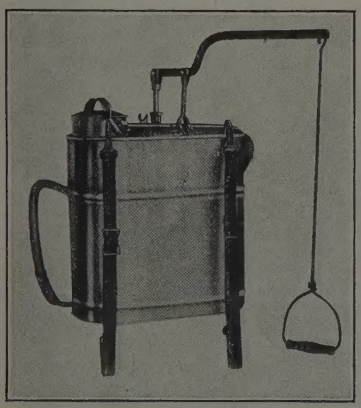

Fig. 15.—Knapsack sprayer suitable for spraying low-growing plants. (Author's illustration.)

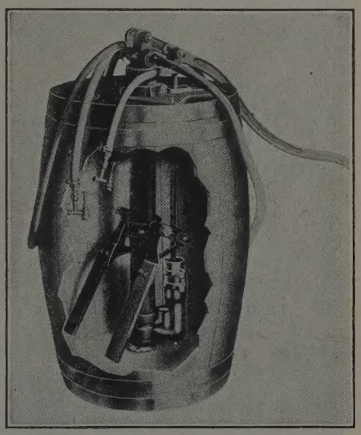

Fig. 16.—Barrel sprayer suitable for orchard or similar large-scale work. (Author's illustration.)

spraying should be made as prescribed for kerosene emulsion, but it should be noted that for summer treatments of trees in foliage the kerosene emulsion is preferable, as it is less likely to cause injury.

Miscible Oils.

Under the heading "miscible oils" are to be designated several proprietary preparations which are essentially petroleum oils with the addition of a vegetable oil and an alkali, to secure ready saponification with water. These come in concentrated solutions and the spray is prepared by adding a specified amount of water. In point of convenience they leave little to be desired. Miscible oils have come into use in place of kerosene or crude petroleum, either pure or in emulsions, and have a distinct usefulness as winter sprays about the same as have the concentrated lime-sulphur solutions. As has

been indicated, the petroleum oils are at times the cause of injury to twigs and fruit buds, in extreme cases killing the trees. It is a question of judgment whether, under conditions of severe scale infestation, the petroleum oils or the sulphur solutions should be used. The petroleum oils, on the whole, are more effective and the danger of injury from them is less to pome than to stone fruits.

The practicability of making miscible oils at home has been investigated by Prof. C. L. Penny, and he has shown it to be entirely feasible, as detailed in the publications cited below.[1]

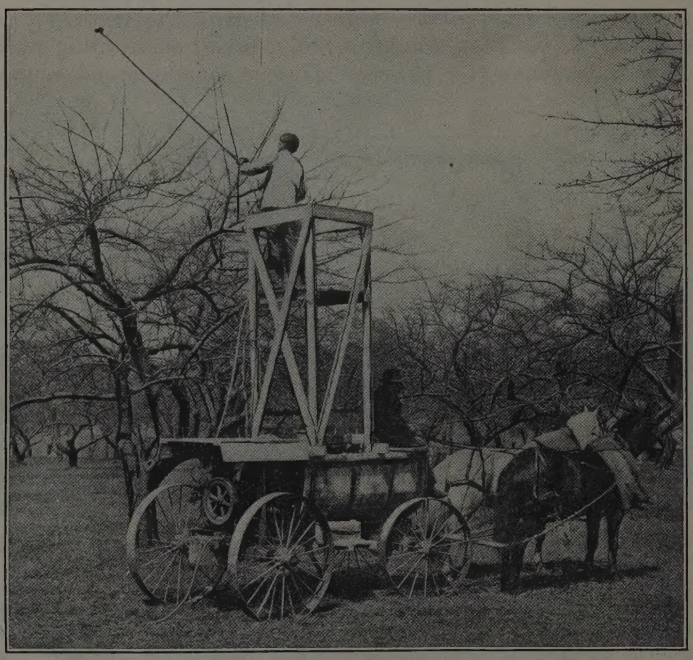

FIG. 17.—Gasoline power spraying outfit for use in large orchards. (Original.)

SOAP WASHES.

Practically the only soap wash which has come into extended use against the San Jose scale is that made from fish oil. Fish-oil soap is used mostly on dormant trees, being employed at the rate of 2 pounds to the gallon of water.

A potash fish-oil soap is preferable and should contain not more than 30 per cent of water. Soda soaps, while perhaps cheaper, will be

[1] Penny, Charles L. Petroleum emulsions. Del. Agr. Col. Expt. Sta., Bul. 75, 39 p., June 18, 1906.
Penny, Charles L. Miscible oils: How to make them. Penn. State Col., Bul. 86, 20 p., fig., March, 1908.

likely to solidify on cooling when used at the strength just indicated, and are hence forced through the spray-nozzle with difficulty. For spraying trees in foliage the soap should be used at the rate of 1 pound to 3 or 4 gallons of water, or somewhat weaker.

SPRAYING APPARATUS.

For the successful application of sprays to trees and plants infested with the San Jose scale some form of spraying apparatus is necessary. For small plants, as low trees, ornamental hedges, etc., a bucket pump (fig. 14) or a knapsack pump (fig. 15) will be satisfactory. The barrel pump (fig. 16) will permit of more thorough work and will be suitable for orchards of some size. It may be placed in a wagon or cart or mounted on a sledge. For large commercial orchards the hand-power tank, or gasoline outfits, are, of course, employed. (See fig. 17.) It is quite practicable in case but a few trees in the yard are to be treated to apply the wash on the limbs and branches by means of a brush, or even with old cloths. Fish-oil soap is excellent in such cases. Severe pruning of the trees is usually desirable to simplify the work of treatment, and also to produce a new growth of noninfested wood.

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